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ABSTRACT

The Advances in Biological Sciences program at California State University described in this report has provided 160 high school, junior high, and fifth and sixth grade science teachers with lectures, laboratories, lesson planning, and implementation guidance in forefront biology over the past 3 years. Over 200 program lessons have been incorporated into local classrooms, and dissemination has taken place locally through teacher inservice and nationally through five journal articles and conferences. Program materials are used in about 25 states. Lessons have been incorporated into the Curriculum Guides for Biology and Life Science published by the Los Angeles Unified School District. The program consists of lecture-discussion-lecture planning sessions held throughout the school year and a summer laboratory program. A key to the success of this program is the ability of the research scientists to convey forefront concepts to teachers in an exciting and easily understandable way. All presenters are active researchers and most are winners of teaching awards. Utilization of a Nobel laureate in the program provides great inspiration to the teachers. Copies of related articles by the author are appended. Contains 22 references. (Author/SM)

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AASCU/ERIC Model Programs Inventory Project

The AASCU/ERIC Model Programs Inventory is a two-year project seeking to establish and test a model system for collecting and disseminating information on model programs at AASCU-member institutions--375 of the public four-year colleges and universities in the United States.

The four objectives of the project are:

- To increase the information on model programs available to all institutions through the ERIC system
- To encourage the use of the ERIC system by AASCU institutions
- To improve AASCU's ability to know about, and share information on, activities at member institutions, and
- To test a model for collaboration with ERIC that other national organizations might adopt.

The AASCU/ERIC Model Programs Inventory Project is funded with a grant from the Fund for the Improvement of Postsecondary Education to the American Association of State Colleges and Universities, in collaboration with the ERIC Clearinghouse on Higher Education at The George Washington University.

ABSTRACT

Advances in Biological Science. Steven B. Oppenheimer, Ph.D., Project Director, California State University, Northridge.

Advances in Biological Science, funded by the National Science Foundation, the Joseph Drown Foundation, Valley Federal Savings, California State University, Northridge and Los Angeles area schools, has provided 160 high school, junior high and fifth and sixth grade science teachers with lectures, laboratories,lesson planning and implementation guidance in forefront biology over the past 3 years.Over 200 program lessons have been incorporated into local classrooms and dissemination has taken place locally through teacher inservice and nationally through 5 journal articles and conferences. Program materials are used in at least 25 different states and portions of the program have been incorporated into the Curriculum Course Outlines for Biology AB and Life Science AB of the Los Angeles Unified School District, that reach thousands of teachers and eventually millions of students. Key factors in the success of this model include: selection of project faculty who are outstanding teachers and scientists; presentation of major advances and not narrow research topics; provision of laboratories that are brief, yet forefront and easy to implement; provision of detailed, clear write-ups and high quality blackline masters and color slides; and, utilization of the services of a Nobel laureate to inspire the teachers , indicating their importance to the the health and welfare of this nation. Supported by National Science Foundation grants TEI 8550011, TEI 8650081, TPE 8650081, grants from the Joseph Drown Foundation, Valley Federal Savings and assistance from California State University, Northridge and Los Angeles area schools.

INTRODUCTION

Advances in Biological Science, funded by the National Science Foundation, has provided 160 excellent high school, junior nign, and 5th and 6th grade science teachers in the Los Angeles area with lectures, discussions, laboratories, lesson planning and implementation guidance in rorefront biology over the past three years. The program has been disseminated nationally through 5 publications in two journals (The Science Teacher and The American Biology Teacher) and national use of materials developed in the program (in 25 states). In Los Angeles, in addition to tne teachers actually participating in the program, thousands or teachers and eventually millions or students will benefit because many or the lessons developed in Advances in Biological Science have been incorporated into the Curriculum guides for Biology and Life Science publisned by the Los Angeles Unified School District. Program participants have also disseminated the lessons through workshops and conferences.

NEEDS AND GOALS

The alarming results of a just-published study on "Science Achievement in Seventeen Countries" indicate that U.S. science students ranked at or near tne bottom, with an educational pattern similar to that of developing countries where sharp contrasts between elite schools and others are common (Science Achievement in Seventeen Countries: A Preliminary Report, 1988). The results in the United States led the authors to comment that "for a technologically advanced country, it would appear that a re-examination of how science is represented and studied is required (Science Achievement in Seventeen Countries: A Preliminary Report, 1988). There has been a common misconception by some that students in the United States are more competent in Biology than in the Physical Sciences because more teachers have a Biology background. The results of tne 1988 study were eye-openers. The United States scored last (13th out or 13 countries) in Biology Achievement of 12th graders, 11th out or 13 for Chemistry and 9th out of 13 for Physics (Science Achievement in Seventeen Countries: A Preliminary Report, 1988). Although this simplistic result does not show how good our "best" are, the picture is truly alarming.

Recent studies show that the most widely used secondary biology textbooks omit or treat poorly some of the most important forefront areas, such as genetic engineering/recombinant DNA technology (Moyer and Mayer, 1985). The Office or Technology Assessment reported that 63% of adults in this nation did not know what DNA was (U.S. Congress, Office of Technology Assessment, 1984).

The rapid explosion of new information in the biological sciences has left many or the nation's teachers unable to keep up with these advances (Oppenneimer, et al., 1988; Fiske, 1987).

The United States and other nations are presently utilizing the new biology to begin to solve some of the major problems that have plagued mankind: production of genetically engineered hormones and medicines to combat diseases such as diabetes and malaria; detection of inherited diseases by examining individuals' DNA; production of monoclonal antibodies for detection and treatment of diseases including some forms of cancer; production of genetically engineered plants that are resistant to diseases and require little fertilizer; utilization of new technology to begin to sequence the entire human genome that may lead to an understanding of development, aging, cancer and other diseases (Oppenheimer, et al., 1988; Oppenheimer, 1987b; Caskey, 1987; Hood, et al., 1987; Glick, 1986).

Advances in biology are not only occurring in the broad field of biotechnology. The field of marine biology, for example, is yielding important information with respect to: the discovery of new systems of life that are based upon chemical energy instead of solar energy; ocean warming trends and their impact on world weather, oceanic conditions and marine organisms; use of infrared imagery via satellite to measure primary production in the sea; discovery of magnetic receptors in marine animals; progress in aquaculture and so on (Oppenheimer, et al., 1988).

Major findings in fields such as epidemiology are providing clues about new strategies to prevent cancer, heart disease and other maladies that afflict us all (Oppenheimer, et al., 1988; Oppenheimer, 1988; Oppenheimer, 1987a; 1987b).

In order to develop a new generation of scientists who will carry on this progress and in order to produce a scientifically literate public that not only knows what DNA is, but also knows enough about modern biology to make informed decisions about its role in improving the health and welfare of the U.S. and the world, we must update pre-college biology in our schools (U.S. Congress, Office of Technology Assessment, 1984; Fiske, 1987).

Three years ago we gathered a group of leading scientists known for forefront work and outstanding teaching, faculty from our school of education, Allyn Arnold, Sid Sitkoff and Jerry Garner, specialists from the Los Angeles Unified School District, outstanding teachers in the district and members of the Greater Los Angeles Teachers Science Association. We examined the curriculum in Biology of the district and developed a program to update it. This plan became what we now call Advances in Biological Science, which has to date resulted in bringing new biology into the classrooms of the 160 teacher participants, into the district as a whole and into numerous classrooms nationwide, as will be described in detail.

PROGRAM OUTLINE

1. Selection and Honoring Participants

We believe that the application procedure should be open to assure that we do not miss an outstanding teacher by some sort of designed nomination process. Application forms were developed and have been distributed to every high school and junior high school in the Greater Los Angeles Unified School District and every elementary school in the District. Distribution is facilitated by Gerald Garner (secondary schools), Sid Sitcoff (elementary schools) and Allyn Arnold (Gifted/Talented Programs). In addition, news articles in local papers plus a full-page announcement in "Inertia Tree", the publication of the Greater Los Angeles Teachers Science Association, publicize the program. Forty outstanding teachers (3/4 secondary, 1/4 upper elementary) plus five teacher-leaders were selected each year. A record of outstanding teaching is the primary criterion used, but careful attention is paid to including teachers of minority and disadvantaged students. This is accomplished by the conscious selection of excellent teachers, with attention to attracting under-represented teachers, from as many schools with large minority and low income student populations as possible. Selections are made by a committee consisting of Dr. Oppenheimer, Dean Hernandez, three advisors from the School District (Allyn Arnold, Gerald Garner, Sid Sitcoff) and several outstanding teachers . Participants in the program are honored by a banquet and award social, news releases and certificates signed by the honorary program chair, Nobel laureate Francis Crick. Participants receive $400 stipends plus 3 units of credit. Many alumni return year after year with no stipends at all.

2. Program Activities

The program consists of lecture-discussion-lesson planning sessions held on alternate Thursdays, 4:00 - 6:00 p.m. throughout the school year and a summer laboratory program. The first lecture-discussion hour consists of presentations by the distinguished scientists and is followed by lesson planning groups (2 high school, 1 junior high, 1 upper elementary) led by especially outstanding teacher leaders Connie Sparks, Dorothy Moote, Roxie Esterle, Bruce Gurnick and Gerald Richer, who also meet with the presenting scientists to help plan their presentations. Written lesson plans developed by the groups are the vehicle for bringing the forefront concepts to the classroom. They also provide excellent evaluation information. Participants who produce excellent lesson plans have surely learned well. Written reports of incorporation of the lesson plans into individual teacher curricula are made by the teachers and on-site evaluators (Oppenheimer, Hernandez, Sitcoff, Arnold, Garner, Sparks, Moote, Esterle, Gurnick and Richer) for use in the final report to NSF. We feel that, in our hands, a year-around program that keeps teachers with us over extended periods builds relationships that might not develop as well in summer-only programs.

A key to the success of this sort of program is the ability of a research scientist to convey forefront concepts to teachers in an exciting and easily understandable manner. The scientist presenters meet two criteria for inclusion in the program: 1) work in a forefront area of biology, and 2) a record of distinguished and exciting teaching. As can be seen by the highlights of the presenting scientists' qualifications that follow, they are active researchers and most are winners of teaching awards (distinguished professor designations; only 4 professors of over 1,000 receive this honor each year). All presenters have also been designated by Dr. Oppenheimer as outstanding based upon his attending their classes or invited addresses and through formative evaluations by teachers in this program.

Prior to the program, all teachers are given a book produced by the project directors called Advances in Biological Science Handbook. This book contains the concept summaries and recent references provided by the presenting scientists. It is designed to:

1) acquaint the Teacher-Fellows with the ideas before each session
2) provide a review of the key concepts
3) help formulate lesson plans for the classroom
4) provide recent key references for further reading, and
5) provide professional quality black-line masters for immediate incorporation of program charts, diagrams and drawings into the classroom.

The black-line masters are specially designed charts, diagrams and drawings that are used by the scientists in the presentations. This facilitates easy transfer of the concepts to the classroom by providing high quality visual aids for overhead projection.

This is the first of a 5-part set of materials developed in the program. Part II is a Lesson Plans book, containing the best of the Lesson Plans on Advances in Biological Science that are developed by the teacher participants. Part III consists of a series of videotapes of the distinguished presentations; Part IV consists of copies of the color slides used by each scientist in their presentation. Part V is a set of program publications in The Science Teacher and The American Biology Teacher that disseminate program lessons and materials nationally.

The lecture/discussion portion of the program is presented by outstanding scientist-educators (their names follow their presentation) followed by group lesson planning sessions.

The topics presented in the lecture/discussion program follow. Each year the topics are examined through formative evaluations utilizing teacher input in the form of questionnaires and by examining the record of incorporation of the lessons into the classrooms. Topics and presenters are changed accordingly.

Lecture/Discussions, Alternate Thursdays
4-6 P.M. During the Academic Year

Social Hour Honoring NSF Fellows and Information Session	
Advances in Biology of Cancer	Dr. Steven B. Oppenheimer
Advances in Cell Biology	Dr. Phillip Sheeler
Advances in Nutrition (Heart Disease and Cancer)	Dr. Rosalyn B. Alfin-Slater
Advances in Plant Biotechnology	Dr. William Emboden
NOBEL LAUREATE ADDRESS Tne Two DNA Revolutions (rollowed by banquet)	Dr. Francis H.C. Crick
Recombinant DNA Technology	Dr. Joyce B. Maxwell
Advances in Marine Biology	Dr. Larry G. Allen
Advances in Aquaculture	Dr. Earl Segal
Advances in Human Ecology	Dr. Joseph Moore
Advances in Biology of Aging	Dr. Marvin H. Cantor
Advances in Developmental Biology	Dr. Steven B. Oppenheimer
Computer Simulation in Biological Research	Dr. Phillip Sheeler
New Careers in Biology	Dr. Steven B. Oppenheimer

Each year Dr. Crick, Nobel laureate makes a different presentation. Topics included:

The Two DNA Revolutions

How Do We See?

The Chemistry of Memory

The Function of Dream Sleep

Summer Laboratory Component - Daily 8-5 P.M.
The Week Immediately Following the Close of the Academic Year

The Summer Laboratory portion of the program consists of the following experiments, all shown to be easily implemented by the teachers in their classrooms.

Genetic Engineering - Plasmid Insertion	Drs. Hendrickson and Jones
Human Karyotype	Dr. Maxwell
Sea Urchin Fertilization and Development	Dr. Oppenheimer
Experiments on Sea Urchin Embryo Cell Adhesion	Dr. Oppenheimer
Removal of the Nucleus from a Large Cell	Dr. Oppenheimer
Immunochemical Test for Hormone Detection	Dr. Sparling
Extraction of DNA from Tissues and Cells	Dr. Sheeler
Particle Isolation in Cell Biology	Dr. Sheeler
Marine Biology Laboratory	Drs. Allen and Wells
Marine Biology Snorkeling Excursion	Drs. Allen and Wells

Results: Over 200 program lessons have been implemented in Los Angeles Classrooms of program participants. Nationwide, portions of the program have appeared in 5 articles in the American Biology Teacher and The Science Teacher. Teachers in 25 different states have requested the use of our program materials and some program exercises have been incorporated into the Curriculum Guides for Biology and Life Science published by the Los Angeles Unified School District that reach thousands of teachers and eventually millions of students. Program participants and the Project Directors and Facilitators also disseminated program components through in service workshops, conferences and meetings, locally and nationally.

Conclusions and Recommendations: Formative evaluations lead us to conclude:

1. Key factors in the success of this model are: a) selection of Project Faculty who are not only leaders in their fields but are also award-winning teachers, b) the most successful workshops are those that present overviews in advances in the field and not narrow research topics, c) the most successful laboratories are those that convey key forefront concepts but are short in length and use easily available supplies, and d) implementation and dissemination of project lessons are greatly enhanced by the immediate provision of detailed, clear write-ups and high quality blackline masters and color slides.

2. Utilization of a Nobel laureate in the program provides great inspiration to the teachers. It is also a symbol of the importance placed upon their jobs as educators of our nation's youngsters in a field that is critical to the health and welfare of the United States.

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Advances in Biological Science

Steven B. Oppenheimer
Joyce B. Maxwell
Larry G. Allen

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It is a major task for educators to keep up with the advances in biology that occur almost daily. The National Science Foundation-supported "Advances in Biological Science" program (NSF-ABS), now in its third year, was designed to provide Los Angeles teachers with developments at the cutting edge of the biological sciences and to disseminate this information nationally. The program features scientists, including Nobel laureate Francis Crick, known for outstanding research contributions as well as award-winning teaching.

This article is the second in a series in *The American Biology Teacher* of "Advances" papers based on the NSF-ABS program. Here, we review major developments in areas that are at the cutting edge of biology today. The advances selected for this article represent fields as different as cancer and marine biology, the common thread being that exciting new developments have recently occurred in each.

Human Anti-cancer Gene

The topic of cancer biology and oncogenes was reviewed in a recent article in this journal (Oppenheimer 1987). One series of major new developments was not included because the picture was not complete until after the *ABT* article was already in press. It is appropriate to begin this review with this new development in cancer biology because it can be considered one of the most important true breakthroughs in this area.

Retinoblastoma is a cancer of the eye that strikes about one in 20,000 individuals. It usually afflicts infants and young children, often requiring removal of the eyeball. If the cancer is detected early, it can be cured by less radical treatments, including radiation therapy and sometimes by laser surgery or freezing.

Many of those cured of this cancer in early childhood go on to have children. Much to the surprise of early investigators in this area, the children of retinoblastoma survivors came down with the same cancer at an astounding rate as high as 50 percent.

After a thorough analysis of the histories of 48 retinoblastoma patients, Alfred Knudson at the M.D. Anderson Hospital and Tumor Institute in Houston, TX, concluded that this cancer must be the result of two mutations. Two forms of the cancer exist. In hereditary forms, one of the two mutations is passed on from a parent, while the other occurs spontaneously. In non-hereditary forms, both mutations must occur spontaneously (reviewed in Harris 1986).

The picture began to clear when investigators in the mid-1970s and early 1980s found that some retinoblastoma patients possessed a deletion in chromosome 13. The deletion appeared in a region of the chromosome called q14. Ray White and Webster Cavenee found that cells of retinoblastomas lacked the q14 region. This same deletion was found in osteosarcoma cells, a bone cancer that develops at increased frequency in teenagers who survived retinoblastoma (reviewed in Harris 1986).

By combining all these pieces of evidence, it began to appear that retinoblastoma is caused by the absence of the activity of a gene in the q14 region of chromosome 13. In normal cells, this gene preserves division patterns that maintain the normal state. Each individual possesses two copies of chromosome 13, one from each parent. If the q14 region is missing or damaged on one of the two copies of this chromosome, no cancer develops because the presence of the normal q14 region on the second chromosome produces a gene product in sufficient quantity to preserve the normal state.

The gene in q14 can be called an *anti-cancer gene* because it prevents cancer. In hereditary retinoblastoma, the infant received the missing or damaged anti-cancer gene from one parent on one of its copies of chromosome 13. Once a mutation occurs in the second anti-cancer gene on the other copy of chromosome 13, then and only then will the child develop retinoblastoma. Retinoblastoma, therefore, is caused by a recessive mutation. This is right in line with Knudson's conclusions many years earlier that two mutations are required for the development of

this cancer (Figure 1).

Children with hereditary retinoblastoma carry one mutated gene from a parent and spontaneously developed the second mutation in the other copy of chromosome 13 in eye cells. If they also develop the second mutation in bone cells, osteosarcoma will develop. Thus, both retinoblastoma and osteosarcoma are recessive disorders in which the anti-cancer gene in both copies of chromosome 13 must be deleted or damaged (Figure 1).

A feverish race developed to clone the q14 human anti-cancer gene because only by obtaining millions of copies of the gene can its function be properly studied. Thaddeus Dryja, Stephen Friend and Robert Weinberg succeeded in cloning this gene and reported their findings in the October 16, 1986, issue of the journal *Nature* (Friend, et al. 1986).

An understanding of how this anti-cancer gene works may lead to the eventual prevention or even reversal of human cancers.

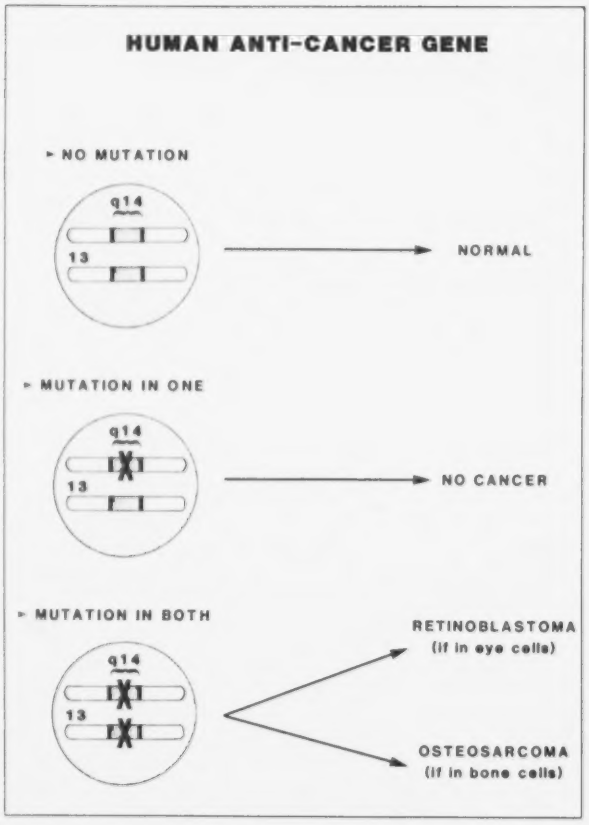

Figure 1. Human Anti-Cancer Gene. Cells are normal if no mutations occur in the q14 region of chromosome 13. If a mutation in the anti-cancer gene in q14 occurs in only one of the two chromosome 13s, cancer is not induced. If, however, such a mutation occurs in both chromosome 13s, retinoblastoma is induced if it occurs in eye cells, while osteosarcoma develops if it occurs in bone cells. The gene in question can be called a human anti-cancer gene because normality is maintained when at least one copy of the gene is functional, while cancer is induced if both copies are inactivated.

The Impact of Recombinant DNA Techniques on the Detection of Huntington Disease Carriers

Huntington Disease is an inherited trait that is typically expressed after the affected individual has had children. Because the trait is dominant, a person undergoing the physical and mental deterioration characteristic of the disease could be advised that each of his or her children has a fifty-fifty chance of suffering the same fate. In the past, identifying individuals who carry the dominant allele leading to disease before the onset of symptoms has been impossible. Recently, techniques used to manipulate DNA for genetic engineering have allowed detection of such individuals with a high degree of accuracy.

When DNA is isolated and exposed to enzymes called restriction endonucleases, the molecules of DNA are broken at specific nucleotide sequences. For example, one such endonuclease called Eco RI (because it was the first such enzyme isolated from *Escherichia coli* strain R) cleaves DNA wherever the nucleotide sequence is

GAATTC
CTTAAG

Because this sequence occurs randomly along any particular DNA molecule, fragments of varying lengths are produced. DNA fragments are readily separated on the basis of size by electrophoresis through an agarose gel; small fragments migrate faster, and thus move farther from the origin than larger fragments. Any DNA thus broken and subjected to electrophoresis produces a reproducible pattern of separated fragments. Interestingly, if DNAs are isolated from two different persons, the patterns may differ slightly. This makes sense, for we know that each person possesses a set of allelic forms of human genes that is different from anyone else, and alleles typically differ by one or a few nucleotides. If, by chance, the nucleotides that distinguish one person's DNA from another's possess a changed sequence recognized by the restriction endonuclease, one DNA will be broken at the sequence and one will not. Such differences in patterns of fragments observed in the DNAs isolated from different individuals are referred to as Restriction Fragment Length Polymorphisms or RFLPS. Such differences are inherited and can be followed in a human pedigree like any other inherited trait.

The breakthrough in identifying carriers of the Huntington Disease allele came when the disease was observed to show close linkage to a particular restriction fragment called G8 (Gusella 1985). In a

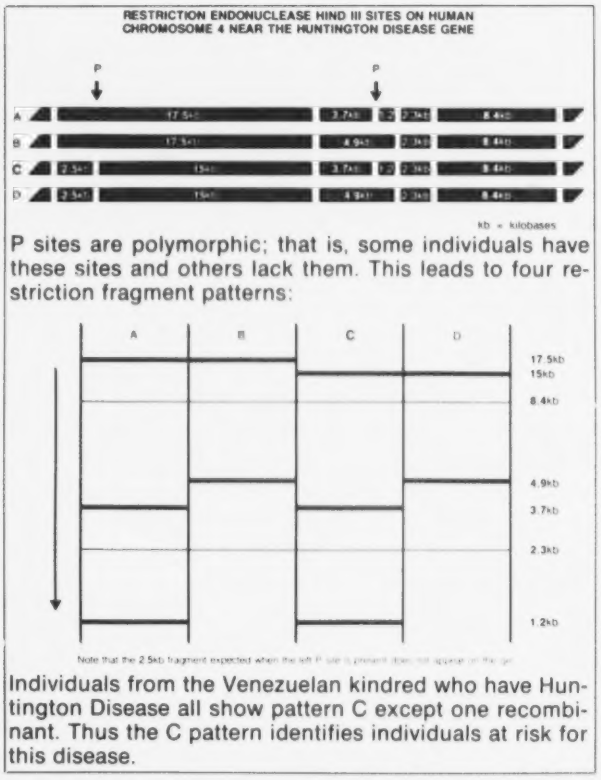
RESTRICTION ENDONUCLEASE HIND III SITES ON HUMAN CHROMOSOME 4 NEAR THE HUNTINGTON DISEASE GENE
P
P
A
B
C
D
kb = kilobases
P sites are polymorphic; that is, some individuals have these sites and others lack them. This leads to four restriction fragment patterns:
A
B
C
D
17.5kb
15kb
8.4kb
4.9kb
3.7kb
2.3kb
1.2kb
Individuals from the Venezuelan kindred who have Huntington Disease all show pattern C except one recombinant. Thus the C pattern identifies individuals at risk for this disease.

Figure 2. Molecular Genetics in the Detection of Huntington Disease. Fragments of DNA that are produced when DNA from different individuals is cleaved by the restriction endonuclease Hind III. Fragments are separated by size by electrophoresis on agarose gels. The arrow in the lower portion of the figure indicates the fragments' direction of movement. Differences in the fragments produced are inherited and show close linkage to the presence or absence of Huntington Disease in members of a large family studied in Venezuela. The association of pattern C with Huntington disease allows one to predict that individuals with this pattern will develop the disease.

very large family in Venezuela, almost 100 relatives suffer from Huntington Disease, and all except one show the same RFLP (Figure 2). The one exception is a recombinant, indicating the RFLP is not due to the altered gene causing Huntington Disease but rather is a nucleotide change that occurred nearby. Because of the association of the RFLP and Huntington Disease, it is now possible to identify those individuals in this family or in other groups who are likely to develop the disease. Other families in which Huntington Disease occurs are now being analyzed to determine if they will show a similar pattern (Youngman et al. 1986).

The search for associations between a particular RFLP and other inherited disorders is likely to be a fruitful area of investigation for years to come. It is likely that this sort of technology, once fully developed, will become extremely useful in diagnostic medicine.

Advances in Marine Biology

The many fields of marine biology have experienced rapid growth in the last five to 10 years. The task of choosing only a few accomplishments across all these fields was very difficult. We are basing this presentation on the criteria of originality of the advance in its particular field and its overall significance to marine science.

We introduce some of these new discoveries and provide pertinent references for further reading on the subjects. The topics included are:

- deep-sea hydrothermal vent and cold seep communities
- the 1982-83 El Nino event
- satellite technologies for studying the sea surface
- human impact on marine resources and the concomitant effect on marine ecosystems
- magnetic receptors in marine animals.

In 1977, a team of marine geologists studying the characteristics of the ocean floor around a tectonic spreading zone near the Galapagos Islands unwittingly made one of the most significant finds in the history of marine biology. They found an entirely new ecosystem based not on solar energy like other ecosystems on this planet, but rather on chemical energy. Since 1977, this new type of ecosystem, now known as the hydrothermal vent or deep-sea hot spring ecosystem, has been studied intensively by biologists.

Studies have shown that chemosynthetic bacteria form the base of the food chain using hydrogen sulfide as their primary energy source. When the H_2S is oxidized, energy is released which is then used to synthesize organic compounds via the Calvin-Benson cycle (Figure 3).

These chemosynthetic bacteria occur both solitarily and in symbiotic relationships with some major vent animals such as the giant tube worms, giant clams and crabs. In the solitary form, these bacteria are subject to grazing by some vent residents. In the symbiotic form, the bacteria act essentially like chloroplasts in plants providing organic compounds for their hosts, while receiving protection and H_2S from the host and vents. The presence of H_2S rather than heat seems to be the most important factor in determining the presence of "vent" faunae since the heat dissipates very rapidly in 2 degree Celcius water, leaving no noticeable effects a few meters away. Cold seep areas, particularly around Florida, have a similar fauna with the same biochemistry.

Since the early finds at the Galapagos rift, 10 additional hydrothermal vent areas have been discovered throughout the eastern Pacific. It appears that this "new" ecosystem is widely distributed and may even

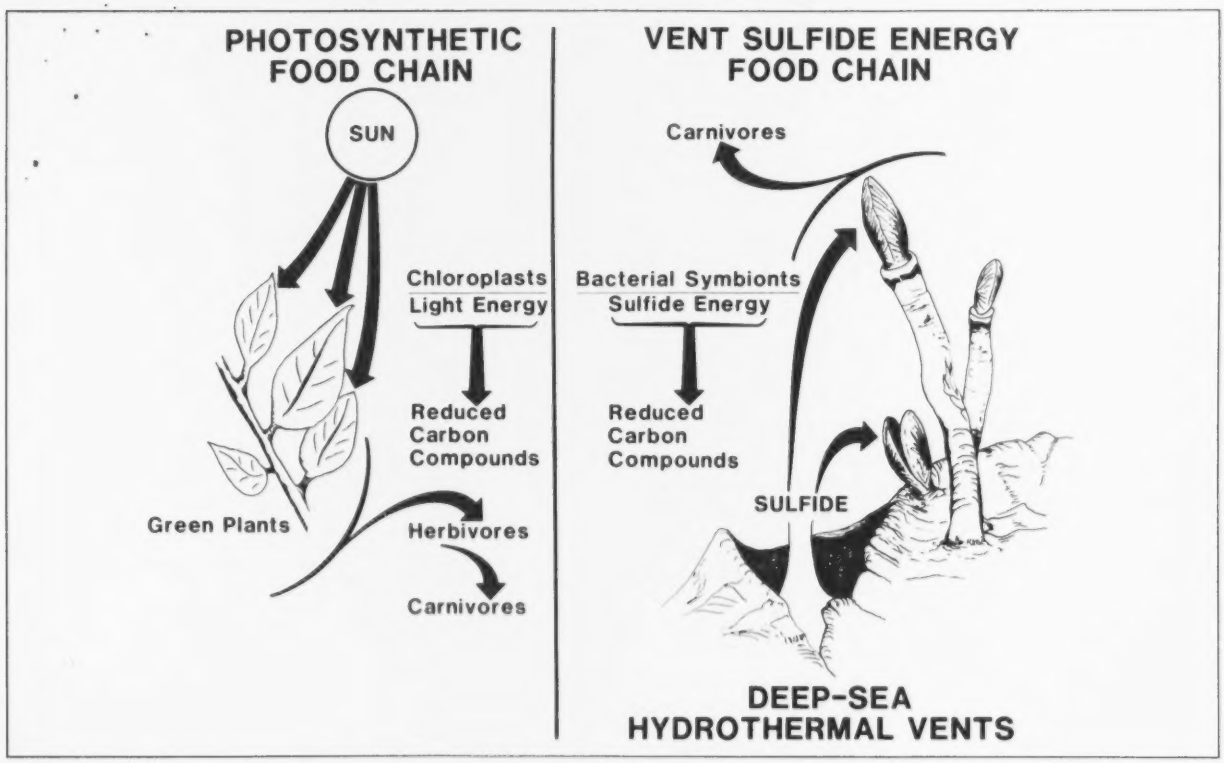

Figure 3. A Comparison of Sunlight-Driven versus Sulfide-Driven (in Deep-Sea Hydrothermal Vent Communities) Food Chains. In photosynthetic chains sunlight is used in the chloroplasts to drive CO_2 fixation via the Calvin-Benson cycle. In the vent tube worm and clam, energy released from sulfide oxidation by bacterial symbionts is used to power the Calvin-Benson cycle for synthesis of reduced carbon compounds (after Jannasch 1984).

be found world-wide (Somero 1984; Jannasch 1984).

In recent years, the single most important phenomenon in the field of marine science was an eastern Pacific warming trend called the El Nino-Southern Oscillation event of 1982-83. This El Nino is significant because of its far reaching effects on world weather, oceanic conditions and populations of marine organisms. El Nino-type events are not rare and occur at fairly regular intervals of about five to 10 years. However, the 1982-83 event was the most severe in recent years and was studied intensively.

El Nino-Southern Oscillations involve changes in atmospheric conditions over the equatorial Pacific Ocean and have a long-range, profound impact on global weather patterns. Results include large-scale changes in climate, such as droughts in normally productive areas and heavy rainfall in normally dry regions.

The 1982-83 El Nino event's impact on the marine environment of the eastern Pacific was equally as profound. A decrease in easterly winds during this period increased the eastward flow of the equatorial counter-current (among others) "piling-up" warm water in the eastern Pacific. This caused reduced upwelling, due to lessened easterly winds, and ocean warming which decreased primary productivity in the eastern Pacific. The lower production had a dramatic impact on marine organisms, with lower population levels resulting in most. The 1982-83 El Nino event also widened the distribution of many marine species into higher latitudes with elevated sea surface temperatures (Canby 1984; Rasmussen 1985).

The use of satellite technology to study the oceans is a recent, promising development. Satellite systems such as Coastal Zone Color Scanner (CZCS) on the Nimbus-7 satellite and Seasat uses absorption-spectral analysis to measure primary production in the sea while infrared imagery can identify sea surface temperatures (to 0.1 degree celcius gradients) for the identification of convergences and fronts (Feldman et al. 1984). The latter has been used to detect concentrations of albacore tuna in the eastern Pacific.

Investigations of human impact on marine resources are not new. Only in recent years, however, has the full impact of one particular human-based overexploitation been realized. Specifically, intensive whaling in the southern oceans near Antarctica has had a dramatic effect on the Antarctic ecosystem. Depletion of baleen whale populations has prevented approximately 150 million tons of krill from being consumed per year. This excess has led to substantial increases in the numbers of seals and espe-

cially penguins, which seem to have established a new equilibrium with the available food resources. This new equilibrium is now threatened by plans of several nations, principally Japan and Russia, to increase the harvesting of krill in the southern ocean (Beddington & May 1982; Laws 1985).

Finally, an understanding of orientation, migration and homing phenomena can be related to magnetic receptors in many types of marine animals. Geomagnetic guidance systems are thought to exist in such diverse forms as bacteria, sharks, rays, tuna and porpoises. It has been postulated that some animals which contain ferromagnetic material (magnetite) may use a magnetic dipole moment (the equivalent of a compass needle) to orient themselves within the earth's magnetic field. In addition, sharks, skates and rays may be able to use their extremely sensitive electroreceptors to detect the weak, directional electric fields induced by currents flowing through the earth's magnetic field. Recently, live strandings of Cetaceans have been related to geomagnetic disturbances. Such impressive finds were unimaginable only 10 years ago (Kalmijn 1982; Klinowska 1986; Walker et al. 1984).

Other topics of interest that could not be discussed in this brief report include: persistent problems of marine pollution, status of world mariculture, community structure of coral reefs, diving physiology of marine mammals and the mechanism involved in the schooling behavior of fish.

A set of full-page size copies of the figures presented in this article, which can be used for overhead projection in the classroom, will be provided at no cost by contacting Oppenheimer.

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17

How Do You Get a Nobelist Into Your Classroom?

Start by asking.

by Steven B. Oppenheimer, Carolyn L. Ellner, and Luis F. Hernandez

In 1986, a teacher inservice training session at California State University, Northridge, featured an unusual component: Dr. Francis H. C. Crick, who won the Nobel prize with James Watson for uncovering the molecular structure of DNA. Crick captivated the teachers with a remarkable account of the thinking that led to the historic discovery, which is a cornerstone of basic biology. Crick also gave his views on "the second DNA revolution," recombinant DNA technology.

A brief encounter

Afterward, Crick posed for a photograph with each teacher and chatted with them for several hours over cocktails and dinner. Later, the teachers received certificates signed by Crick. One teacher called the evening "the greatest event of my professional life." But the teachers weren't the only beneficiaries. Their most advanced students got to attend, and the presentation was videotaped, so the teachers could replay it for the rest of their students. Even Crick himself seemed to relish the audience's evident appreciation and the chance to do something for science education.

Although it is hard to judge the educational impact of this brief encounter with a man who made one of the great discoveries in the life sciences, the experience undoubtedly boosted the teachers' morale. In addition to hearing, first-hand, Crick's personal thoughts and feelings, the teachers were reminded that the great scientists of the world are not all dead and gone—many are not only alive but interested in helping to educate the next generation of scientists.

Crick's visit was part of a program sponsored by the National Science Foundation called Advances in Biological Sciences designed to update high school, junior high, and fifth-grade and sixth-grade science teachers. In its first year, the program presented 43 Los Angeles teachers with the latest in cancer biology, cell biology, electron microscopy, marine biology, and more through lectures, lesson-planning sessions, and labs. But Crick's visit was clearly the highlight.

This experience has convinced us that a visit by a Nobel laureate to a teacher-training program, a school, or a science classroom can enrich both students and teachers. Contact with a Nobelist can make the history of science come alive.

We have compiled a partial list of Nobel laureates in the sciences who live in the United States. You can use the list that follows to invite them to speak, but you don't have to get a Nobel laureate to your school to benefit from it. Students seldom can name any living scientist but Carl Sagan. Simply showing your students this list will remind them that not all the famous scientists are gone.

Nothing ventured

But if you do want to attract a Nobel laureate, here are some tips. Choose one who is close by. Travel is likely to discourage them. Make your first contact with a gracious letter that details how the Nobelist's participation would help your program and science education in general. Be frank about the amount of money you can give as an honorarium. Some Nobelists might come for a nominal amount because of the educational nature of the visit, but be as generous as you can. Spell out in detail exactly what you want presented. Nobelists are used to giving highly technical presentations; ask them to present general views in simple, enthusiastic terms, rather than complex research discussions. Follow up your letter with a phone call. And after the event, your distinguished guest will appreciate and remember a reception and the presentation of an engraved plaque. Until you ask, you'll never know who might say yes. ■

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Nobel laureates

Here are chronological lists of some Nobel laureates in physiology or medicine, physics, and chemistry by name, field of study, year of award, and address.

Physiology or medicine

Thomas H. Weller, polio virus culture, 1954. Dept. of Tropical Public Health, Harvard School of Public Health, Boston, MA 02115.

Frederick Robbins, polio virus culture, 1954. Institute of Medicine, National Academy of Sciences, 2101 Constitution Ave. NW, Washington, DC 20418.

George W. Beadle, gene action, 1958. 1700 E. 56th St., Apt. 401, Chicago, IL 60637.

Edward L. Tatum, gene action, 1958. Rockefeller University, New York, NY 10021.

Joshua Lederberg, genetic organization, 1958. Rockefeller University, New York, NY 10021.

Severo Ochoa, synthesis of RNA and DNA, 1959. Roche Institute, Nutley, NJ 07110.

Arthur Kornberg, synthesis of RNA and DNA, 1959. Dept. of Biochemistry, Stanford Medical School, Stanford, CA 94305.

Francis H.C. Crick, structure of DNA, 1962. Salk Institute, San Diego, CA 92138.

James D. Watson, structure of DNA, 1962. Cold Spring Harbor Lab, Cold Spring Harbor, NY 11724.

Konrad Bloch, cholesterol regulation, 1964. Dept. of Chemistry, Harvard University, Cambridge, MA 02138.

George Wald, visual physiology, 1967. Harvard University, Cambridge, MA 02138.

Robert W. Holley, genetic code and protein synthesis, 1968, Salk Institute, San Diego, CA 92138.

Har Gobind Khorana, genetic code and protein synthesis, 1968. Dept. of Biochemistry, M.I.T., Cambridge, MA 02139.

Marshall Nirenberg, genetic code and protein synthesis, 1968. National Heart, Lung, Blood Institute, Bethesda, MD 20014.

Salvador E. Luria, virus genetics, 1969. M.I.T., Cambridge, MA 02139.

Julius Axelrod, nerve transmittors, 1970. National Institutes of Health, Bethesda, MD 20014.

Gerald M. Edelman, antibody structure, 1972. Rockefeller University, New York, NY 10021.

George E. Palade, cell structure and function, 1974. Yale Medical School, New Haven, CT 06510.

David Baltimore, tumor virus in cells, 1975. Dept. of Biology, M.I.T., Cambridge, MA 02139.

Renato Dulbecco, tumor virus in cells, 1975. Salk Institute, San Diego, CA 92138.

Howard M. Temin, tumor virus in cells, 1975. McArdle Lab, University of Wisconsin, Madison, WI 53706.

Baruch S. Blumberg, infectious diseases, 1976. Institute for Cancer Research, Philadelphia, PA 19111.

D. Carleton Gajdusek, infectious diseases, 1976. National Institutes of Health, Bethesda, MD 20014.

Roger Guillemin, brain hormone, 1977. Salk Institute, San Diego, CA 92138.

Andrew Schally, brain hormone, 1977. Veterans Administration Hospital, New Orleans, LA 70146.

Rosalyn Yalow, radioimmunoassays, 1977. Veterans Administration Hospital, Bronx, NY 10468.

Daniel Nathans, restriction enzymes, 1978. Johns Hopkins Medical School, Baltimore, MD 21205.

Hamilton O. Smith, restriction enzymes, 1978. Johns Hopkins Medical School, Baltimore, MD 21205.

Allan M. Cormack, computer-assisted tomography, 1979. Tufts University, Medford, MA 02155.

Baruj Benacerraf, immunology, 1980. Dept. of Pathology, Harvard Medical School, Boston, MA 02155.

George D. Snell, immunology, 1980. 21 Atlantic Ave., Bar Harbor, ME 04609.

Roger W. Sperry, brain function, 1981. Cal Tech, Pasadena, CA 91175.

David H. Hubel, visual information, 1981. Dept. of Neurobiology, Harvard Medical School, Boston, MA 02115.

Torsten N. Wiesel, visual information, 1981. Dept. of Neurobiology, Harvard Medical School, Boston, MA 02115.

Barbara McClintock, jumping genes, 1983. Cold Spring Harbor Lab, Cold Spring Harbor, NY 11724.

Michael S. Brown, cholesterol receptors, 1985. University of Texas, Dallas, TX 75235.

Joseph L. Goldstein, cholesterol receptors, 1985. University of Texas, Dallas, TX 75235.

Physics

Felix Bloch, nuclear magnetic precision measurements, 1952. 1551 Emerson St., Palo Alto, CA 94301.

Edward M. Purcell, nuclear magnetic precision measurements, 1952. Lyman Lab, Harvard University, Cambridge, MA 02138.

Willis E. Lamb, Jr., hydrogen spectrum, 1955. Dept. of Physics, University of Arizona, Tucson, AZ 85721.

Polykarp Kusch, magnetic moment of an electron, 1955. Dept. of Physiology, University of Texas at Dallas, Richardson, TX 75080.

William Shockley, semiconductors, 1956. Dept. of Electrical Engineering, Stanford University, Stanford, CA 94305.

John Bardeen, semiconductors, 1956. Dept. of Physics, University of Illinois, Urbana, IL 61801.

Walter H. Brattain, semiconductors, 1956. Dept. of Physics, Whitman College, Walla Walla, WA 99362.

Emilio G. Segre, antiproton, 1959. Dept. of Physics, University of California, Berkeley, CA 94720.

Owen Chamberlain, antiproton, 1959. University of California, Berkeley, CA 94720.

Donald A. Glaser, bubble chamber, 1960. Dept. of Molecular Biology, University of California, Berkeley, CA 94720.

Robert Hofstadter, electron scattering and nucleons, 1961. Dept. of Physics, Stanford University, Stanford, CA 94305.

Eugene P. Wigner, atomic nucleus and elementary particles, 1963. Dept. of Math and Physics, Princeton University, Princeton, NJ 08540.

Charles H. Townes, quantum electronics, 1964. Dept. of Physics, University of California, Berkeley, CA 94720.

Julian Schwinger, quantum electrodynamics, 1965. Dept. of Physics, U.C.L.A., Los Angeles, CA 90024.

Richard P. Feynman, quantum electrodynamics, 1965. Cal Tech, Pasadena, CA 91125.

Hans A. Bethe, energy production in stars and nuclear reactions, 1967. Dept. of Physics, Cornell University, Ithaca, NY 14853.

Luis W. Alvarez, elementary particles, 1968. Lawrence Berkeley Lab, Berkeley, CA 94720.

Murray Gell-Mann, elementary particles, 1969. Lauritsen Lab, Cal Tech, Pasadena, CA 91109.

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Robert J. Schrieffer, superconductivity, 1972. Dept. of Physics, University of Pennsylvania, Philadelphia, PA 19104.

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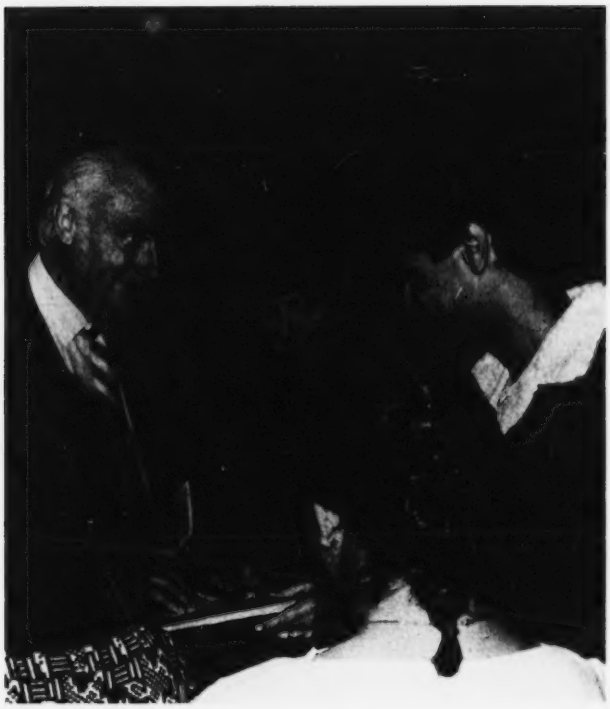

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James W. Cronin, decay of neutral K-mesons, 1980. University of Chicago, Chicago, IL 60637.

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Melvin Calvin, photosynthesis, 1961. Laboratory of Chemical Biodynamics, University of California, Berkeley, CA 94720.

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Paul J. Flory, physical chemistry of macromolecules, 1974. 210 Golden Oak Dr., Portola Valley, CA 94025.

William Lipscomb, Jr., structure of boranes, 1976. Dept. of Chemistry, Harvard University, Cambridge, MA 02138.

Herbert C. Brown, boron and phosphorus compounds in synthesis, 1979. Dept. of Chemistry, Purdue University, West Lafayette, IN 47907.

Paul Berg, recombinant DNA, 1980. Dept. of Biochemistry, Stanford, CA 94305.

Walter Gilbert, base sequences in nucleic acids, 1980. Harvard Biological Labs, Cambridge, MA 02138.

Roald Hoffmann, chemical reactions, 1981. Dept. of Chemistry, Cornell University, Ithaca, NY 14850.

Henry Taube, electron transfer, 1983. Stanford University, Stanford, CA 94305.

Bruce R. Merrifield, proteins, 1984. Rockefeller University, New York, NY 10021.

Herbert A. Hauptman, X-ray crystallography, 1985. Medical Foundation of Buffalo, 73 High St., Buffalo, NY 14203.

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Ten Strategies for Cancer Prevention

By Steven B. Oppenheimer

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Ten Strategies for Cancer Prevention

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Your mother told you to eat carrots because they were good for your eyes. If you heeded her advice, you may have protected yourself from more than poor vision.

Of the 400 000 cancer deaths each year in the United States, at least 200 000 are preventable [1]. This means that the most effective method of cancer control in the near future will most likely be prevention. As science teachers, I think we have an obligation to relay cancer-prevention strategies to our students and suggest they take the information home to their families. To this end, here's an up-to-date summary of strategies for cancer prevention, based on information from studies of population groups, animal experiments, and laboratory work [8,9,10].

In 1775 British physician Sir Percival Pott laid the groundwork for the field of cancer prevention. He observed that all of his patients with cancer of the scrotum had something in common: They were chimney sweeps as children, forced to climb naked through filthy chimneys and were seldom bathed. Pott concluded that the constant irritation produced by the accumulation of soot in the folds of the scrotum resulted in the boys developing scrotal cancer at puberty [11]. When protective clothing and frequent bathing became commonplace among chimney sweeps, cancer seldom developed.

Pott can be considered the father of cancer prevention because his work led to the recognition that specific carcinogens exist and that if contact with them is eliminated some cancers can be prevented. Since the days of Pott, many carcinogens have been identified, and ways to reduce contact with them have been devised. Gloves, masks, and fume hoods are preventive items already familiar to teachers and students. You and your students can carry prevention beyond the science classroom by following these pointers.

1 Stop smoking.

Smoking is the number one single cause of cancer death in the United States. Deaths occur not only from lung cancer but also from cancers of the oral cavity, esophagus, bladder, and more. The many known carcinogens in cigarette smoke include the radioactive element ^{210}polonium and arsenic (see Figure 1 on page 40). Researchers believe that smoking-induced cancers result from a chemical carcinogen effect on tissue as well as from radiation-induced tissue damage.

Statistics indicate that heavy smokers run more than a 1000 percent increased risk of developing lung cancer compared with nonsmokers. It would take about 1 year of breathing Los Angeles smog to equal the amount of carcinogen taken into the lungs in 1 day of smoking. Secondhand smoke is also a risk and should be avoided [12].

What is the evidence that tobacco smoking does indeed cause cancer?

Figure 1. Known carcinogens found in tobacco or in cigarette smoke.

aminostilbene	n-dibutylnitrosoamine
arsenic	2,3-dimethylchrysene
benz-(a)-anthracene	indenol-(1,2,3-cd)-pyrene
benz-(a)-pyrene	5-methylchrysene
benzene	methylfluoranthrene
benzo-(b)-fluoranthrene	β-naphthylamine
benzo-(c)-phenanthrene	nickel compounds
cadmium	n-nitrosomethylethylamine
chrysene	n-nitrosodiethylamine
dibenz-(a,h)-acridine	n-nitrosonanabasine
dibenz-(a,j)-acridine	n-nitrosopiperidine
dibenz-(a,c)-anthracene	n-nitrosopyrrolidine
dibenz-(c,g)-carbazone	^{210}polonium
dibenz-(a,e)-fluoranthrene	

Figure 2. Annual exposure of humans in the United States to various forms of radiation in 1980.[a]

Source	Dose (millirems)
Natural radiation	
Cosmic rays	28
Natural radioisotopes in the body	28
Natural radioisotopes in the soil	26
	82
Manufactured radiation	
Diagnostic X rays	20
Radioactive drugs	2-4
Consumer products (X rays from TV, radioisotopes in clock dials) and building materials	4-5
Fallout from weapons testing	4-5
Nuclear power plants	<1
	30-35
Total	112-117

[a]The source for the data in this figure is the National Research Council, Committee on the Biological Effects of Ionizing Radiations. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation*. National Academy Press, 1980.

Figure 3. Occupational carcinogens and industries in which exposure to carcinogens is common.

Industrial carcinogens

acrylonitrile, 4-aminodiphenyl, arsenic compounds, asbestos, auramine, benzene, benzidine, benzidine salts, beryllium, bis-(chloromethyl) ether, cadmium compounds, carbon tetrachloride, chloromethyl, chromium compounds, magenta, methyl ether, mustard gas, α-naphthylamine, β-naphthylamine, nickel compounds, oils, soot, tars, vinyl chloride

Industries and occupations

adhesives, artificial leather, asbestos, asbestos textiles, automobile brakes, biochemical synthesis, burnishing, cement mixing, chemical industry, construction, coal, coke gas, detergent industry, dry battery production, dye making, furniture, glue production, insulation production, petrochemical production, plastics, putty making, rubber industry, shipyards, shoes, water pipe cutters, welding, wood preservation, woodwork

Figure 4. Substances used in medicine that have carcinogenic activity in the laboratory.

Substance	Condition
coal tar ointments	skin dicease
Flagyl	vaginal infection
griseofulvin	scalp ringworm, athlete's foot
lindane shampoos	head lice
Phenacetin	headache, pain

First, there is correlative data. Eighty percent of lung cancer patients are smokers. Most other lung cancer patients either work in high-risk settings where they have inhaled carcinogens over long periods or have been exposed to high radon levels [8,9,10]. Second, there is experimental evidence showing that the agents listed in Figure 1 cause cancer in lab animals. Most of the substances directly damage cell DNA, resulting in cancer-causing mutations [8]. Most agents that cause cancer in lab animals also cause cancer in humans.

2 Do not use smokeless tobacco.

Smokeless tobacco in the form of snuff and chewing tobacco is a major cause of oral cancer, now even seen in young people. Research shows that users of smokeless tobacco have greatly increased risks of developing mouth, throat, tongue, and other cancers of the oral cavity [1].

3 Avoid excessive exposure to radiation.

The most common cancers in this country are the skin cancers, with overexposure to sun the major cause. Ultraviolet radiation from sun can cause damage to skin cell DNA, which, if not repaired properly, may result in cancer. Never burn. Wear protective clothing and use sunscreens to block ultraviolet radiation. (See Figure 2.)

Avoid unnecessary numbers of medical and dental X rays. X rays can be lifesavers, but it is prudent to ask whether they are really needed and not just part of a routine [7].

Be aware of exposure to radon, a naturally occurring form of radiation. Hazardous levels of radon gas have been found in some homes, seeping in from underlying soil and rock. Maintaining good ventilation may reduce

radon accumulation, and kits are available to test homes for the presence of the gas. A listing of over 100 sources for kits was published in the July 1987 issue of *Consumer Reports* ("Radon Detectors," pp. 440–447).

The evidence that radiation causes cancer is extensive. Skin cancer is more prevalent in the sun belts of the United States, especially among fair-skinned people and those who work outdoors [8]. Many cases of leukemia and other cancers appeared in people exposed to the atom bomb blasts in Japan, with a significant correlation between cancer incidence and dose received. In addition, statistics show that cancers occur more often in people exposed to radiation in the early days of the nuclear industry or to high radiation doses used to treat ringworm of the scalp or other conditions [8].

4 Avoid contact with and breathing chemicals.

Some chemicals are carcinogenic, especially after years of exposure. Likely carcinogens include asbestos, benzene, chromium, nickel compounds, carbon tetrachloride, wood dust, leather dust, soots, tars, and oils, as shown in Figure 3.

Practice caution when handling chemicals. Use protective clothing, respirators, or dust masks. Wash often and use adequate ventilation. These are familiar admonishments to science teachers, but they are worth saying one more time. Artists should be careful when dissolving paint pigments, because some pigments contain heavy-metal carcinogens such as cadmium. Pigment dusts should not be inhaled.

Avoid contact with and breathing aerosol products, solvents, and paint thinners. If you do your own brake jobs, wear a protective mask or respirator because the dust from most brake linings contains asbestos. Some hair dyes, cosmetics, and drugs contain substances that may be carcinogenic (see Figure 4). Small quantities of carcinogens also can be found in some municipal drinking water (see Figure 5 on page 42); activated carbon filters are available that can effectively remove most of these agents [4,9].

The evidence that these chemicals cause cancer comes from human occupation studies and laboratory experiments. Statistics show that workers in the occupations listed in Figure 3 who are exposed to the chemicals also listed are at increased risk for developing a variety of cancers [8,9,10]. These same chemicals cause cancer in laboratory animals [8,9,10].

5 Eat fewer fats and salt-cured or smoked foods.

Studies of eating habits of population groups indicate that people who eat low-fat diets have much-reduced rates of colon-rectum, breast, and prostate cancers. Specific evidence suggesting that high-fat diets cause cancer comes from studies of Japanese people who have migrated to the United States. They display significantly higher rates of colon-rectum, breast, and prostate cancers than their Japanese relatives, with a 5-fold to 10-fold increase in death rates from colon and prostate cancer for themselves and for their children [3].

Reduce fat consumption by eating lower-fat meats, such as poultry and fish, and vegetable sources of protein, such as beans. Cut down on high-fat dairy products, such as high-fat cheeses. Switch to low-fat milk and cheese products.

Hot dogs, bologna, salami, bacon, and other luncheon and breakfast meat products are often salt-cured, which means they contain the preservative sodium nitrite. This preservative forms carcinogenic nitrosamines at frying temperatures or in the body as a result of the combination of nitrites and amines, which are digestive products of proteins. Nitrosamines are associated with increased risk of some cancers including stomach cancer [3]. These foods are usually high in fat anyway.

Smoking, charring, or heavily browning foods produces some of the same carcinogens found in burning tobacco [2], so you should decrease your consumption of foods prepared this way.

6 Don't drink alcohol heavily.

Heavy alcohol consumption, defined by some studies as more than 120 milliliters per day, is a known cause of cancers of the oral cavity, throat, esophagus, stomach, bladder, and liver [2]. Heavy drinkers are at increased cancer risk overall [1].

7 Do not eat moldy foods.

Cheeses such as blue cheese contain molds that are perfectly safe. It is the molds that should not be present that are unsafe. Some molds produce potent carcinogens such as aflatoxins. Store nuts and grains in dry places to avoid mold growth [2].

8 Eat more fruits, vegetables, and grain.

Eat more fruits and vegetables rich in beta carotene, vitamin A, and vitamin

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C, as well as whole-grain products rich in vitamin E and fiber. In cultures where the major part of the diet consists of fruits, vegetables, and whole-grain products, cancers of the digestive tract are rare. Beta carotene and vitamins A, C, and E appear to be anticarcinogens, reducing the formation of carcinogens in the body as a result of their antioxidant properties.

Fresh fruits and vegetables and whole-grain products are also rich in fiber, which dilutes and speeds the exit of body wastes, limiting the ability of carcinogens in the wastes to act on the wall of the digestive tract. Drinking plenty of water also helps reduce the effect of carcinogens on the gut wall.

Figure 6 lists dietary anticarcinogens and the foods containing them. In addition, research suggests that vitamins B12 and folic acid *may* help reduce the risk of some cancers, including smoking-induced lung cancer. [13]. No evidence, however, exists to support the idea that these vitamins can prevent lung cancer in heavy smokers.

Consuming megadoses of vitamins in pill form is not a safe way to provide the body with anticarcinogenic vitamins. Megadose supplements of vitamins such as A or of minerals such as selenium could be very toxic and even fatal. The anticancer effects of fresh fruits and vegetables and whole-grain products may be due not only to the agents in Figure 6 but also to yet undiscovered trace elements that may be potent anticarcinogens [2].

The evidence that foods containing beta carotene, vitamins A, C, and E, and high levels of fiber reduce cancer risk comes from laboratory and population studies. In the laboratory, if researchers eliminate vitamin A from the diet of lab animals, the body tissues undergo changes similar to those observed after treatment with carcinogens. A dietary deficiency of vitamin A in laboratory animals enhances their susceptibility to chemical carcinogens [8,9].

In humans, people whose diets are very low in vitamin A show increased incidence of lung and bladder cancers. And, research has shown that vitamin C inhibits the formation of carcinogens in the gut [6].

The evidence upon which these new dietary guidelines is based is indirect and correlative and does not prove that you can prevent cancer by changing your eating habits. But because definite proof may take years to acquire, the guidelines, although based on soft data, are worth following. A diet low in fat and high in fruits and vegetables is also recommended to prevent heart disease [5].

9 Use caution in your sexual contacts.

Some cancers may be caused by sexually transmitted viruses. For example, some researchers have found that cervical cancer risk is increased in women with a history of genital herpes or papilloma virus infections [8,9,10]. Know your sexual partner; know his or her medical history. Avoid sex with partners suffering from an active form

Figure 5. Some of the carcinogens in the drinking water of some U.S. cities. (Note that chloroform, which forms as a result of water chlorination, is uniformly present.)[a]

Known carcinogens or precarcinogens	New Orleans, La.	Miami, Fla.	Seattle, Wash.	Philadelphia, Pa.	Cincinnati, Ohio	Tucson, Ariz.	New York, N.Y.	Grand Forks, N.Dak.
Benzene	X	X		X	X			
Chloromethyl ether	X							
Vinyl chloride		X		X				
DDT	X				X			
Dieldrin	X	X	X		X			
Hexachlorocyclohexane					X			
Bis (2-chlorethyl) ether	X			X				
Carbon tetrachloride	X	X		X	X		X	X
Chloroform	X	X	X	X	X	X	X	X
Heptachlor	X	X		X	X	X		
Pentachlorobiphenyl					X			
Trichlorobiphenyl					X			
Carbon disulfide	X	X		X	X		X	X

[a]The source for the data in this figure is R.H. Harris, T. Page, and N.A. Reiches. "Carcinogenic Hazards of Organic Chemicals in Drinking Water." *Origins of Human Cancer*. Cold Spring Harbor, N.Y.: Cold Spring Harbor Laboratory, 1977.

of genital disease. Cleanliness and condoms reduce the risk of transfer of a sexually transmitted virus.

10 Avoid obesity.

Maintain a lifestyle that prevents obesity. Obesity is associated with increased risk of some cancers as well as of many other diseases [9].

These cancer-prevention strategies are a good start to demonstrating that everyone can take actions to reduce their cancer risk. But they are just that, a start. Follow up with consciousness-raising activities. One exercise that hits home is to have students complete a questionnaire or write an essay on their lifestyle and dietary habits, followed by essays on how they will change their habits in light of the cancer-prevention strategies they have learned about in the classroom. Or, encourage your students to keep dietary and lifestyle diaries on their own or with their families. They could also do surveys of eating habits of their extended families or neighbors.

A trip to a local cancer research lab would show students what scientists are doing in the field, which would be especially useful for students considering careers in biology or medicine. Students could start a cancer resource library for their school or set up a booth at a school or community health fair. Publishing a brochure for high school students on cancer prevention would require your students to use research skills, as well as to add some new skills to their repertoire.

We need to generate enough enthusiasm about preventing cancer that our students actually absorb the information we present and take that information home to their families. If we can do that, then we will have played a major role in reducing the number of future cancer deaths in the United States. ■

Figure 6. Some dietary anticarcinogens.

Anticarcinogen	Mode of action	Food sources
Beta carotene and vitamin A	antioxidant	carrots, apricots, broccoli, cantaloupe, chard, collards, cress, dandelion leaves, endive, kale, mustard greens, turnip leaves, persimmon, winter squash (hubbard, butternut, acorn, and pumpkin)
Vitamin C (ascorbic acid)	antioxidant (blocks nitrosamine formation)	broccoli, brussels sprouts, cantaloupe, orange, grapefruit, strawberries
Vitamin E (tocopherols)	antioxidant	vegetable oils, whole-grain products, meat, milk, vegetables
Selenium	helps body destroy peroxides	most balanced diets, especially fish, cabbage, broccoli, cauliflower, brussels sprouts, rice, breads

Note

Full-page copies of the figures that appear in this article are available for overhead projection at no cost from the author. A video, *Cancer Prevention: A Way of Life*, recently produced by California State University at Northridge, is also available through the author on a free-loan basis.

Note

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Advances in Cancer Biology

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The area of cancer biology is one of the most exciting in all of science today. Knowledge about the causes of cancer changes on an almost daily basis and, in the past several years, more important discoveries have been made than in all of the previous decades combined. This article will review this field and provide diagrams that can be used to bring this information to students in the classroom.

Causes of Cancer

Most of the evidence available today suggests that a normal cell can be transformed into a cancer cell when certain genes become activated. Three major groups of cancer causing agents (carcinogens) have been identified. They are: (1) certain viruses, (2) radiations and (3) certain chemicals.

Viruses (Figure 1) cause many animal cancers such as cat leukemia and are associated with some human cancers including T-cell leukemia, Burkitt's lymphoma, nasopharyngeal carcinoma and cervical cancer (Marx 1986). Cancer viruses either contain a central core of DNA or RNA. This viral genetic information becomes incorporated into the cellular genome and, in some way, transforms the cell into a cancer cell.

Radiation (Figure 2), whether it be nuclear radiation or ultraviolet radiation from the sun, breaks cellular DNA, and if the breaks are not properly repaired, the cell may become transformed into a cancer cell.

Finally, the chemical carcinogens (Figure 3), such as those found in cigarette smoke (Figure 4), usually react with the bases in DNA. Most carcinogens act in one of three ways: (1) they attack a base and change its base-pairing properties, resulting in a mutation in the next round of DNA synthesis; (2) they damage DNA in a way that temporarily blocks DNA synthesis, causing alternate DNA synthesis pathways to be set into motion that result in replication errors (mutations); (3) they insert themselves between base pairs causing bases to be lost or added during subsequent DNA replication (Marx 1986; Miller 1970; Oppenheimer 1985 for review).

Oncogenes

The most exciting of all recent work in cancer biology concerns the study of oncogenes. As mentioned above, most carcinogens cause cancer by their action on DNA. It appears that certain cellular genes, termed protooncogenes, can become activated forming oncogenes—genes that can cause the cell to become cancerous. The function of protooncogenes in

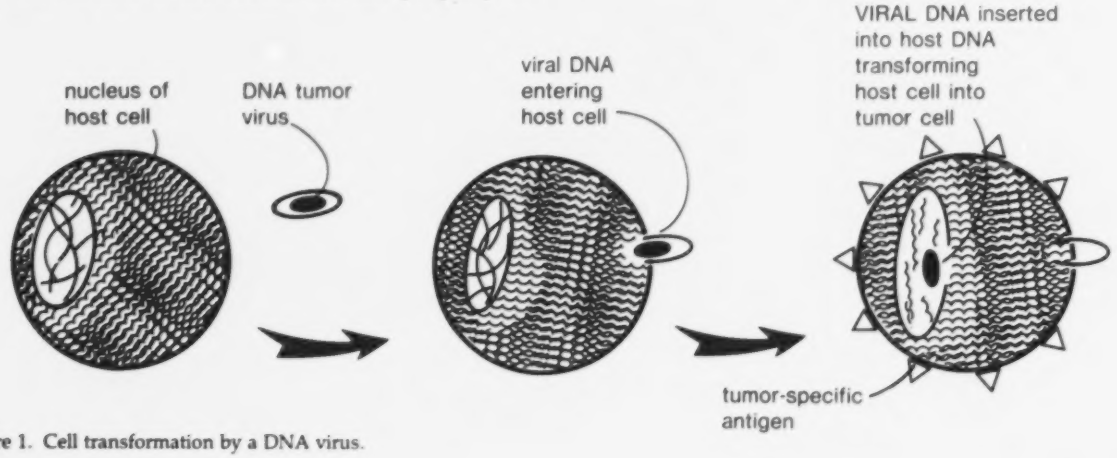
nucleus of host cell
DNA tumor virus
viral DNA entering host cell
VIRAL DNA inserted into host DNA transforming host cell into tumor cell
tumor-specific antigen

Figure 1. Cell transformation by a DNA virus.

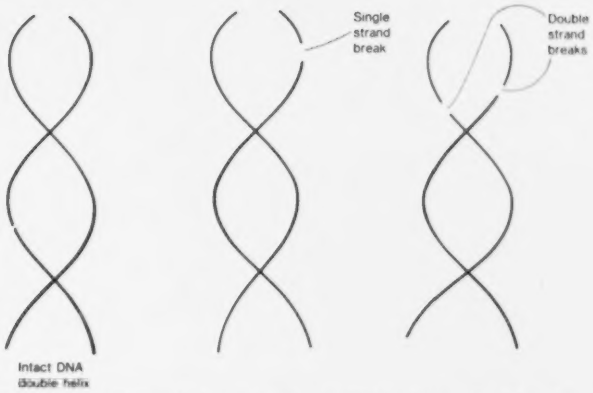

Figure 2. Radiation induces breaks in DNA. Unrepaired breaks may lead to cancer.

cells is not well understood but once the protooncogenes become active in synthesis of either altered or excessive quantities of their messages, then they are termed oncogenes and can cause cellular transformations (Thompson, Challoner, Neiman & Groudine 1986; Paul 1984).

The notion of oncogenes really began with the work of Howard Temin decades ago. Temin proposed that cancer-causing viruses act by incorporating a cancer-causing gene into the cell's chromosome set. This notion gave rise to the concept of oncogene (cancer-causing gene). As this idea developed in many laboratories, it was further suggested that an oncogene might be present in the inactive form in normal cells and in some way activated in cancer cells, or alternatively, an oncogene could be brought into the cell by a virus. The actual discovery of oncogenes in human and animal cells was the result of combining new technologies of molecular biology, molecular genetics and cell biology to seek these predicted genes. This discovery (Weinberg 1983), which will be described briefly below, was perhaps the most significant of all findings in cancer research, for it is providing the beginnings of the understanding of the molecular basis of cancer.

Isolation of Human Cancer Oncogene

Weinberg and colleagues were first to isolate an oncogene from human cancer cells (Weinberg 1983; Paul 1984; Oppenheimer 1985). They isolated DNA from human bladder cancer cells, fragmented it into small pieces and added the DNA fragments to a culture of mouse cells (strain 3T3). Some of the mouse cells became transformed into cancer cells. This experiment strongly suggested that an oncogene present in the human DNA fragments was able to transform non-cancer cells into cancer cells (Figure 5).

In another experiment, the DNA fragments from the human bladder cancer cells were separated into a large number of fractions and each was tested for ability to transform the mouse cells. Only a single DNA fragment could induce transformation. This fragment contained the human bladder cancer oncogene (Weinberg 1983; review in Oppenheimer 1985).

As mentioned in our previous discussion, it was felt generally that there must be a counterpart of this bladder cancer oncogene in normal cells. Indeed, this was found to be the case, for a DNA fragment was isolated from normal human bladder cells that was very similar to the bladder cancer oncogene. The only difference was a one-base change in the coding sequence. A guanine in the normal DNA was replaced by a thymine in the oncogene. Thus, for this particular human bladder cancer, the oncogene is a mutant form of a normal gene, the difference being in only one single base. It is tempting to speculate, therefore, that a carcinogen may induce bladder cancer by causing such a one-base mutation in the appropriate gene.

Oncogenes and Cancer

The puzzle of the molecular basis of cancer is beginning to clear, but many questions still must be answered. One question is how are oncogenes activated? In other words, how do the normal counterparts of oncogenes become active oncogenes? One way, as shown by the bladder cancer story, is by induction of a mutation in the normal gene, causing it to become an active oncogene. In recent months, other activation mechanisms also have been discovered. One mechanism involves translocating the protooncogene to a chromosomal region that promotes gene activity so that the newly located oncogene produces excessive quantities of its messenger RNA (Paul 1984). For example, patients with chronic myelogenous leukemia have a translocation between chromosomes 22 and 9. This causes a specific pro-

4-Aminobiphenyl	Magenta
Arsenic Compounds	Carbon Tetrachloride
Asbestos	Acrylonitrile
Auramine	Mustard Gas
Benzene	Wood Dust
Bis (Chloromethyl) Ether	Leather Dust
Chromium	Beryllium
Hematite	Isopropyl Oil
Nickel	2-Napthylamine
Vinyl Chloride	Soot, Tars, and Oils
Benzidine	

Figure 3. Carcinogens or suspected carcinogens associated with occupation.

tooncogene to move from its normal location in chromosome 9 to chromosome 22. At this new location, the rate of synthesis of the oncogene messenger RNA is eight-fold greater than when the gene is in chromosome 9. This excess amount of oncogene messenger RNA, which leads to synthesis of excess amounts of the protein coded by the oncogene, may be a major factor that causes cancer. Figure 6 provides a summary of some of the oncogenes that so far have been discovered.

It has long been thought that many cancers occur as a result of a two-step process: (1) initiation and (2) promotion. This was suggested more than 60 years ago by observations made by Peyton Rous in which cancers appeared able to remain in a dormant state until they were activated by an irritating substance. The first step, initiation, is believed to involve conversion of a normal cell into a latent tumor cell. The second step, promotion, triggers the cancer cells to grow in an uncontrolled manner. Many experiments confirmed this concept (reviewed in Oppenheimer 1985). It was shown that if the skin of mice was painted once with specific agents such as methylcholanthrene or urethane, few, if any, tumors developed. If that same area, at a later time, was painted with other substances such as croton oil, skin cancers developed. The first group of agents that must be applied first, and appear to induce latent tumor cells are called initiators, while the second group that must be applied second, and cause the cancers to grow, are called promoters. Most initiators cause mutations in DNA and it is believed that initiation may be a mutational event. Promotion appears to be an event in which initiated cells (latent tumor cells) are stimulated to divide. It is likely that many cancers in humans result from the two-step process. This

Aminostilbene	N-Dibutylnitrosamine
Arsenic	2, 3-Dimethylchrysene
Benz (a) anthracene	Indenol (1,2,3-cd) pyrene
Benz (a) pyrene	5-Methylchrysene
Benzene	Methylfluoranthene
Benzo (b) fluoranthene	B-Napthylamine
Benzo (c) phenanthrene	Nickel compounds
Cadmium	N-Nitrosodimethylamine
Chrysene	N-Nitrosomethylethylamine
Dibenz (a,c) anthracene	N-Nitrosodiethylamine
Dibenz (a,e) fluoranthene	Nitrosonornicotine
Dibenz (a,h) acridine	N-Nitrosonanabasine
Dibenz (a,j) acridine	N-Nitrosopiperidine
Dibenz (c,g) carbazone	N-Nitrosopyrrolidine
	Polonium-210

Figure 4. Carcinogens in cigarette smoke.

Human bladder cancer isolated

↓

DNA isolated from cancer

↓

Bladder cancer DNA fragmented

↓

Fragments added to culture of mouse 3T3 cells

↓

Some of the mouse cells take up the DNA fragments, and some of the DNA becomes integrated into a mouse chromosome

↓

Some mouse cells are transformed

Figure 5. Isolation of human bladder cancer oncogene.

may be why cancers usually take years or decades to develop. Precancerous conditions often develop first (which may represent initiation), followed many years later by cancers, which finally may develop after promotion occurs. How do oncogenes fit into this two-step model of cancer induction?

There is a growing body of evidence that suggests that at least two different oncogenes may be responsible for induction of cancers. Some oncogenes may be responsible for the initiation process (sometimes termed immortalization), while the products of others cause promotion (sometimes termed transformation). For example, normal skin cells can be transformed into cancer cells by sequential treatment first with *myc* oncogene DNA and then with *ras* oncogene DNA. *Myc* appears to act in the initiation process, while *ras* in promotion (reviewed in Oppenheimer 1985) (Figure 6).

In order to really begin to understand the molecular basis of cancer, we must know the nature of the proteins coded for by oncogenes and how these proteins are able to transform cells into cancer cells. The first part of this problem has been solved. We know the nature of many oncogene proteins. The second part, that is, how do oncogene proteins transform cells, remains poorly understood.

Figure 7 provides an overview of some of the classes of known oncogene proteins. As can be seen, some oncogenes code for specific enzymes that phosphorylate proteins (tyrosine kinases, other protein kinases), nuclear proteins, growth factors, or GTP-binding proteins. A little is known about how some oncogene proteins may make cells abnormal. As mentioned above, some oncogenes code for enzymes that phosphorylate proteins (protein kinases). These enzymes may make cells abnormal by phosphorylating proteins that are involved in maintaining normal cell structure and function. For example, phosphorylation of proteins that help cells adhere to

each other and help cells maintain their internal architecture, may interfere with these functions. The *src* oncogene kinase (Figures 6 and 7) can also phosphorylate a lipid, which may lead to a whole series of changes that eventually cause altered control of cell division (reviewed in Oppenheimer 1985). Growth factors produced by some oncogenes (Figure 7) may stimulate continuous division and in this way lead to a cancerous state. The key to an understanding of the molecular basis of cancer may be uncovered once we know exactly how oncogene protein products are involved in causing cellular transformation. One fact is clear—these proteins must interfere directly or indirectly with the regulation of cell division because continuous, unregulated cell division is the primary characteristic of cancer cells (Paul 1984).

Cancer Cell Alterations

Cancer cells differ from normal cells in two fundamental ways: (1) they divide in an unregulated manner; and (2) they eventually detach from the tumor and spread around the body. Somehow, the protein(s) produced by one or more than one oncogene must alter the cell so that it loses its growth regulation and enables it to spread. In recent years, a whole body of information on changes that occur in cancer cells that may be responsible for uncontrolled growth and spread has been developed out of thousands of experiments. It is useful to summarize this information here. Cancer cells do not adhere well to each other. This is partially responsible for their ability to spread. The reasons for this altered adhesion are not clear but it is known that: (1) cancer cells often secrete large quantities of proteolytic enzymes and other enzymes that probably help them invade other tissues and probably cause alteration in cell surface molecules that may be responsible for maintaining cell-cell adhesion; (2) cancer cells possess altered cell surface molecules, and altered mobility of these molecules. Cancer cells take up nutrients at a faster rate than normal cells, which may help them divide continuously. Malignant cells also have a poorly organized cytoskeleton (Figure 8). The lack of well organized bundles of cytoplasmic cytoskeletal elements in cancer cells probably plays an important

Oncogene	Source*
abl	Mouse leukemia, human leukemia cells
B-lym	Chicken and human lymphoma cells
erbA	Chicken leukemia
erbB	Chicken leukemia
ets	Chicken leukemia
fes	Cat sarcoma
fgr	Cat sarcoma
fms	Cat sarcoma
fos	Mouse sarcoma
fps	Chicken sarcoma
Ha-ras	Rat sarcoma; human and rat carcinoma cells
Ki-ras	Rat sarcoma; human carcinoma, sarcoma, and leukemia cells
mil	Chicken sarcoma
mos	Mouse sarcoma, mouse leukemia cells
myb	Chicken leukemia and human leukemia cells
myc	Chicken leukemia; human lymphoma cells
N-ras	Human leukemia and carcinoma cells
raf	Mouse sarcoma
rel	Turkey leukemia
sis	Monkey sarcoma
ros, ski, src, yes	Chicken sarcoma

*Indicates a retrovirus unless indicated as a cell.

Figure 6. Some oncogenes and their sources.

Protein	Oncogene
Tyrosine kinase	abl, fes, fgr, fps, ros, src, yes
Other protein kinases	erbB, fms, mil, mos, raf
Nuclear proteins	B-lym, fos, myb, myc, ski
Growth factor	sis
GTP-binding proteins	Ha-ras, Ki-ras, N-ras

Figure 7. Class of oncogene proteins.

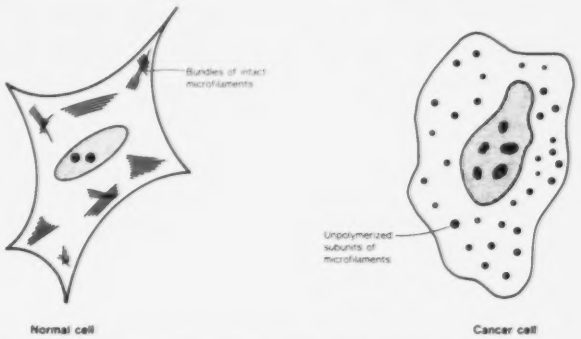

Figure 8. Cytoskeletal elements in normal versus cancer cell.

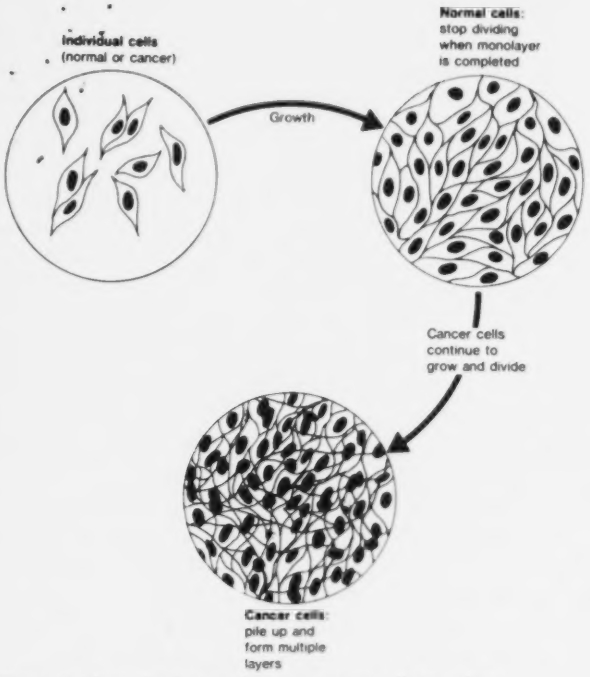

Figure 9. Growth of normal versus cancer cells in culture.

role in their ability to detach from a stable tissue pattern (review in Oppenheimer 1985).

Perhaps the take home lesson on cancer cell properties is best seen in tissue culture. Figure 9 shows normal cells in culture continue to divide until they touch each other on all sides, forming a monolayer. Somehow, cell contact or cell density tells normal cells to stop dividing. Cancer cells, on the other hand, do not respond to cell contact or increased density of cells as normal cells do. Cancer cells continue to divide and pile up, forming multiple layers and clumps. Cancer cells, therefore, appear to have lost the ability to control their division and do not respond to the signals that tell normal cells to stop growing (Ungar, Geiger & Ben-Ze'ev 1986).

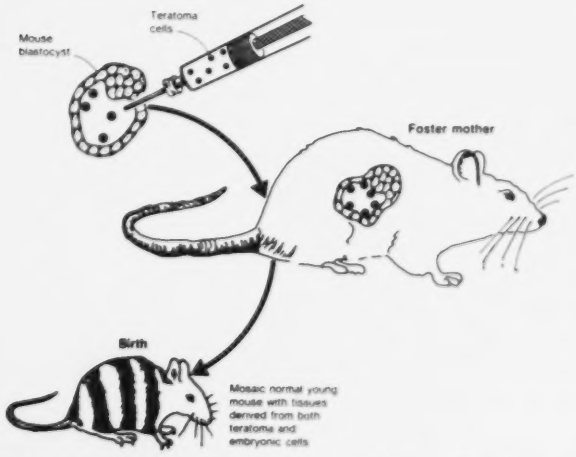

Figure 10. Normalization of teratocarcinoma cells grown in normal mouse embryo.

The Reversal of Malignancy

Can cancer cells revert to normalcy? Is the malignant state reversible? These questions are most intriguing and have been partially answered by a series of elegant experiments. Illmensee and Mintz inoculated teratocarcinoma cells (a type of cancer) into normal mouse embryos. The teratocarcinoma cells carry a gene for dark fur, while the normal embryo cells have a gene for white fur. The embryo (containing the injected cancer cells) was grown in the uterus of a female mouse. The mouse that developed from the injected embryo had no cancer, yet it possessed tissues derived from both the teratocarcinoma cells (black fur) and from normal cells (white fur) (Figure 10). The environment of the cells seems able to cause cancer cells to normalize! This experiment, along with others, suggests that it may eventually be possible to treat cancer effectively by altering the environment of the cells in a way that can normalize the cancer. The malignant state, at least in some cancers, appears to be reversible. The future will tell us if it is possible to induce normalization at the clinical level (Mintz and Illmensee 1976; Oppenheimer 1985 for review).

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Figure References

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Antioncogenes

by Steven B. Oppenheimer

The answer to cancer?

What causes cancer? At one level, we know some of the answers—radiation, certain chemicals, diet, exposure to certain viruses. And we can use this knowledge to avoid exposing ourselves to these dangers [6]. But the effects of radiation, chemicals, and so on must be understood at the cellular level.

We know that cancer is the result of sequential changes in DNA—changes probably brought on by carcinogens. An initiation event, possibly a mutation, occurs and is followed by a promotion event, which causes the initiated cells to divide uncontrollably [4,5]. Any explanation of cancer must, then, account for the two-step initiation/promotion scenario.

One mechanism proposed for these events is the expression of *oncogenes*, or dominant cancer-causing genes. Oncogenes have been identified in a variety of cancers. When inserted into some cell lines, they confer on the cells malignant characteristics. Normally repressed, oncogenes could be activated by mutations, in some cases induced by external factors such as exposure to chemicals. But oncogenes have never been proven to cause *human* cancer.

Only recently have biologists identified a possible alternate mechanism in *antioncogenes*, or genes whose presence may prevent tumors from developing and, conversely, whose absence may encourage malignancy. An early hint of the existence of these tumor-suppressor genes came in 1969 when Henry Harris and his colleagues found that malignancy was suppressed when malignant and nonmalignant cells were fused *in vitro*, even though the complete genetic complements (including any cancer-causing genes) of both groups of cells remained intact [2]. However, the mechanism for the suppression of the cancer remained a mystery.

Research on familial retinoblastoma, a cancer of the eyes, added pieces to the puzzle. Retinoblastoma afflicts about 1 in 20 000 infants and young children and is curable only if detected early. Children of retinoblastoma survivors develop the cancer at rates as high as 50 percent. This fact indicates a genetic component to the disease. As told in a review in *Nature* [2] in 1986, A. G. Knudson analyzed the histories of 48 retinoblastoma patients and hypothesized that familial retinoblastoma develops as a result of double mutations affecting both alleles at a genetic locus called RB-1. The first mutation is probably inherited, and a second occurs spontaneously in the normal homologous chromosome sometime after birth. For retinoblastoma carriers, who start life with one mutated chromosome, if the normal chromosome is destroyed in any single cell among the millions of cells in the retina, then retinoblastoma is

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likely to develop.

In the 1970s through the mid 1980s, a variety of observations suggested that Knudson's model was correct. It appeared that the defect was a deletion in chromosome 13 in a region called q14. The same deletion was found in osteosarcoma cells, a bone cancer that frequently develops in teenagers who have survived retinoblastoma. Researchers eventually concluded that when the normal chromosome 13 spontaneously mutates in the q14 region in eye cells, retinoblastoma develops; when the mutation occurs in bone cells, osteosarcoma forms. The cancers, therefore, appear to be caused by the absence of gene activity in the q14 region of chromosome 13. Normal cells possess two copies of the retinoblastoma antioncogene, one in the q14 region of each chromosome 13. (See Figure 1.)

Stephen Friend and his colleagues succeeded in cloning a 70-kilobase fragment of DNA that corresponded to the retinoblastoma antioncogene, and reported their findings in 1986 [1]. The gene was sequenced, but there was still no direct demonstration that the absence of RB-1 caused the development of a tumor. Nor was there proof that the gene, when present, could prevent cancer. The evidence that would warrant the label "antioncogene" was still circumstantial.

A direct demonstration that specific genetic material could reverse cancer was made by Bernard Weissman and his colleagues in their work with Wilms' tumor, a cancer of the kidneys that afflicts small children [7]. This malignancy develops in cells that have deletions in the p13 region of both copies of chromosome 11. Working with mice, Weissman and his co-

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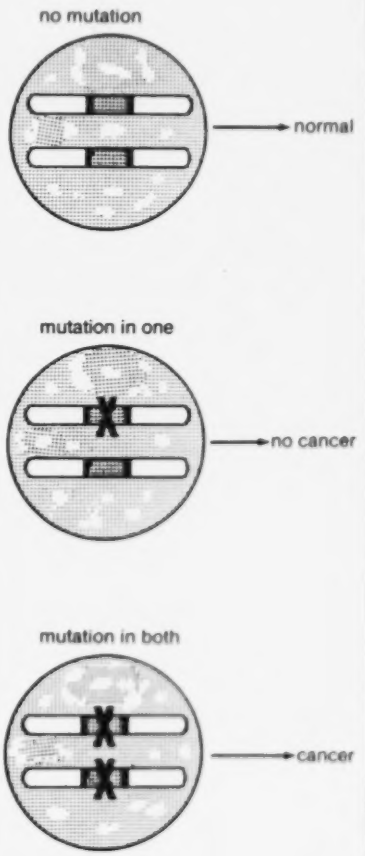
Figure 1



workers inserted a single copy of normal chromosome 11 into Wilms' tumor cells and found that the cells would no longer produce malignancy.

The researchers also tried inserting chromosome 13 (carrying the retinoblastoma antioncogene) as well as a second chromosome thought to carry another antioncogene. Neither prevented the Wilms' tumors from developing. These experiments directly implicated chromosome 11 as the carrier of the antioncogene(s) that blocks the development of Wilms' tumor.

Weissman's work also failed to support the oncogene model. The expression of a variety of oncogenes was the same in both the malignant Wilms' tumor cell lines and in the Wilms' lines that had received the inserts of normal chromosome 11 and subsequently lost their malignancy.

Other cancers have been tentatively associated with the lack of genes: A deletion in chromosome 3 is often found in renal carcinoma and in small cell carcinoma of the lung, and the loss of an allele on chromosome 5 is often present in cancer of the colon [3].

Until oncogenes are directly shown to cause human cancer, the antioncogene model appears very plausible. In other words, many human cancers may be caused not by the activation of an oncogene, but by inactivation or destruction of tumor-suppressor genes present in all healthy cells. ■

References

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Note

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